THE APPROACHING TOTAL ECLIPSE OF THE SUN.[1]

II.

THE considerations which led me, in 1871, to employ a spectroscope without collimator may here again be summarised. If in an ordinary spectroscope, the straight slit be replaced by a circular one, bright rings replace the bright lines which are ordinarily seen in radiation spectra, and since in the solar surroundings we have chiefly to deal with radiation phenomena, the chromosphere and corona themselves can be used during an eclipse as ring slits, and on account of their distance, a collimating lens can be dispensed with.

In the report on the eclipse of 1875, by Dr. Schuster and myself, the principles of the method, as applying to photographs taken during totality, were stated as follows (*Phil. Trans.*, 1878, Part 1, p. 139):—

"Supposing that the corona and chromosphere only send out the same homogeneous light, one image only will appear on the sensitive plate, the only effect of the prism being to displace the image. As far as the protuberances are concerned we know they give a spectrum of bright lines, and we expect, therefore, to find on the plate each protuberance represented as many times as it contains lines in the photographic region. The different protuberances would be arranged in a circle round the sun, and these circles would overlap or not, according to the dispersive power of the prism and the difference in refrangibility of the lines. . . . If the corona gives a series of bright lines we shall find a series of outlines on the photographs similar to that corresponding to the protuberances. . . . If we find that part of the corona gives a continuous spectrum, that part alone will be drawn out into a band."

To this it may be added, that successive photographs will differ on account of the difference of phase. One part of the chromosphere will be visible at the beginning of totality, and another part at the end. The smaller prominences visible at the beginning of totality are subsequently eclipsed by the moon, and their spectra are consequently absent from later photographs, while a new prominence region makes its appearance. In the same way, the part of the corona the spectrum of which is photographed will vary at different phases, but only in the lower parts.

The results obtained by Prof. Respighi and myself during the eclipse of 1871 in India, in which part of the attack consisted in the employment of slitless spectroscopes—a method of work at which we had arrived independently—indicated the extreme value of such observations.

For my own observations in 1871 I had arranged a train of five prisms without either collimator or observing telescope. "I saw four rings with projections defining the prominences. In brightness, C came first, then F, then G, and last of all 1474K. Further, the rings were nearly all the same thickness, certainly not more than 2′ high, and they were all enveloped in a band of continuous spectrum" (NATURE, vol. v. p. 218, 1872).

Respighi's observations were made with a telescope of 4½ inches aperture, with a large prism of small angle in front of the object-glass. The principal results obtained by him were as follows (NATURE, vol. v. p. 237, 1872):—

"At the very instant of totality, the field of the telescope exhibited a most astonishing spectacle. The chromosphere at the edge, which was the last to be eclipsed, . . . was reproduced in the four spectral lines, C, D_3, F and G, with extraordinary intensity of light. . . .

"Meanwhile the coloured zones of the corona became continually more strongly marked, one in the red corresponding with the line C, another in the green, probably coinciding with the line 1474 of Kirchhoff's scale, and a third in the blue perhaps coinciding with F."

"The green zone surrounding the disc of the moon was the brightest, the most uniform and the best defined."

My observation (Brit. Assoc. Report, 1872, p. 331) was made intermediately between the two observations of Prof. Respighi. The observations may be thus compared:—

Respighi	C	D_3	...	F.G.	Chromosphere and prominences at beginning of totality.
Lockyer	C	1474 (faint)		F.G.	Corona 80 secs. after beginning of totality.
Respighi	C	1474 (strong)		F.	Later.

I had no object-glass to collect light, but I had more prisms to disperse it, so that with me the rings were not so high as those observed by Respighi, because I had not so much light to work with; but such as they were, I saw them better, because the continuous spectrum was more dispersed, and the rings (the images of the corona) therefore did not overlap. Hence, doubtless Respighi missed the violet ring which I saw; but both that and 1474 were very dim, while C shone out with marvellous brilliancy, and D_3 was absent.

In arranging for the eclipse of 1875 in Siam and the Nicobars, the method was further developed by the introduction of photography, and the first results of this extension were given in the Report of the Eclipse Expedition of that year. They showed clearly that with the rapid dry plates of to-day a considerable increase of dispersion might be attempted.

The object-glass employed on this occasion had an aperture of 3¾ inches and a focal length of 5 feet, while the prism had a refracting angle of 8 degrees.

Two photographs were obtained with exposures of one and two minutes respectively. Both are reproduced in the Report (*Phil. Trans.*, 1878, vol. clxix. Part i. p. 139), and they show only such differences as can be attributed to difference of phase. The dispersion was very small compared with the size of the sun's image, so that the photographs present the appearance of an ordinary photograph of the eclipsed sun, which is slightly distended in the direction of dispersion. The various prominences each show three images, two of which were identified with $H\beta$, $H\gamma$, while the others were found to correspond to a wave-length of about 3957.

It was suggested (Report, p. 149) that this represented the H and K radiations of calcium, and this is fully confirmed by the results obtained in 1893, to say nothing of results obtained in other eclipses.

I next proceed to remark very briefly upon the photographic results obtained since 1875. In 1878, near the sun-spot minimum, the method was employed by several observers, myself among them, but no *bright* rings were recorded. The maximum sun-spot conditions previously observed had entirely changed; indeed with a slit spectroscope the 1474 line was very feeble, and was only seen by a few of the observers, and hydrogen lines were similarly feeble (*American Journal of Science*, vol xvi. p. 243).

Part of my own equipment for this eclipse consisted of a small grating placed in front of an ordinary portrait camera, and with this I obtained a photograph showing only a very distinct continuous spectrum.[1]

The method was employed by Dr. Schuster in Egypt in 1882; the camera was of 3 inches aperture and 20 inches focal length, with a prism having a refracting angle of 60° (*Phil. Trans.*, vol. clxxv., 1884, p. 262). The single photograph obtained (not reproduced in the Report) was stated to show two rings, which were considered to be due to the lower parts of the corona, and therefore to correspond to true coronal light. The wave-length of one of these rings was measured to be 5315; it is due to the green corona line (1474K). The second was stated to be coincident with D_3.

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[1] Continued from page 157.

[1] With a duplicate grating I observed the spectrum of the eclipsed sun, and again in three different orders, saw nothing but continuous spectrum (NATURE, vol. xviii., 1878, p. 459).

In 1883 the same instrument used in Egypt in 1882 was employed, as well as a 6-inch achromatic telescope, and a concave Rowland grating of 5 feet focus, arranged for taking ring spectra in the first and second orders.

It is stated in the Report (*Phil. Trans.*, 1889 A, vol. clxxx. p. 122) that the photographs "possess no features of interest," and neither reproductions, nor drawings nor measurements are given.

The prismatic camera employed in the eclipses of 1882 and 1883 was again used in the West Indies in 1886. Only the spectra of some prominences seem to have been recorded. There is no mention of rings. The hydrogen lines as well as K and *f* are noted (*Phil. Trans.*, 1889 A, vol. clxxx. p. 319).

While on the one hand the photographic results, to which reference has been made, certainly did not come up to the expectations raised by my observations of 1871; on the other, subsequent solar investigations confirmed my opinion that this was the best way of studying the lower parts of the sun's atmosphere, provided an instrument of much greater light-grasping power could be employed.

I determined, therefore, when arranging for the observations to be made during the eclipse of 1893, to renew the attack with the largest telescope and the greatest dispersion at my command.

The Solar Physics Committee was then in possession of a prismatic camera of 6 inches aperture. I decided, therefore, to employ it, all the more because the work on stellar spectra at Kensington had given abundant proof of its excellence.

The Eclipse of 1893.

The instrument was entrusted to Mr. Fowler, the demonstrator of astronomical physics in the Royal College of Science, who erected it at Fundium in West Africa, and obtained a series of photographs of the greatest value to science. A greater success has never been achieved in eclipse observations.

The object-glass of this instrument, corrected for the photographic rays, was constructed by the Brothers Henry. The correction is such that it is unnecessary to incline the back of the camera, and hence some of the objections which have been made to the use of this form of spectroscope are overcome. The large refracting angle of the prism (45°) obviously increases the value of the instrument for eclipse work.

The camera has a focal length of 7 feet 6 inches, and the spectrum obtained is about 2 inches long from F to K. Rings corresponding to the inner corona are about seven-eighths of an inch in diameter.

The tube is a strong mahogany one, square in section, and it was attached to the declination axis by means of a suitable iron plate. In order to reduce the weight of the instrumental equipment, the heavy iron pillar of the equatorial was replaced by a rough wooden stand which was filled up with concrete after being placed in position. Provision was made for the clock bracket and fine adjustments of the polar axis, and the whole arrangement was quite satisfactory.

Fig. 7 represents the instrument as adjusted for use in latitude 14° 3′ N. When actually at work, the camera was steadied by a stiff wooden rod screwed to the end of the tube, and bearing on the end of the declination axis; this did not interfere with the driving gear and materially contributed to the successful results, as on account of the great weight of the prism it was necessary to bring a large part of the tube forward to the eye end. The brass cap which protected the camera from light other than that which passed through the prism and object-glass, is not shown in the diagram.

As time is very precious during an eclipse, every effort must be made to economise it. I may therefore refer to the manner in which the photographic operations were facilitated by the dark slides used.

The construction of the camera and dark slides, or plate-holders, was based on the plan which I devised for the large pictures of the corona which I hoped to obtain in the West Indies in 1886. The slides are about 13 inches in length by 7 inches broad, and have three compartments, each taking a plate 6 inches by 4 inches.

The camera at the end of the long wooden tube has an opening 6 inches square, and a rectangular frame 24 inches long, with a central aperture 6 inches by 4 inches, and provided with grooves to take the slides, was symmetrically attached to it. A dark slide being placed in the frame, so that the first compartment was opposite the middle of the telescope tube, the shutter was then opened to its full extent, and an exposure made; the plate in the second compartment was next brought to the middle of the frame, by pushing the slide along, and also exposed; again, by moving the slide along, the third plate was brought into position and exposed, after which the shutter was closed and the slide withdrawn. During the exposure of any one of the three plates in a slide, the other two were protected from light by the rectangular frame.

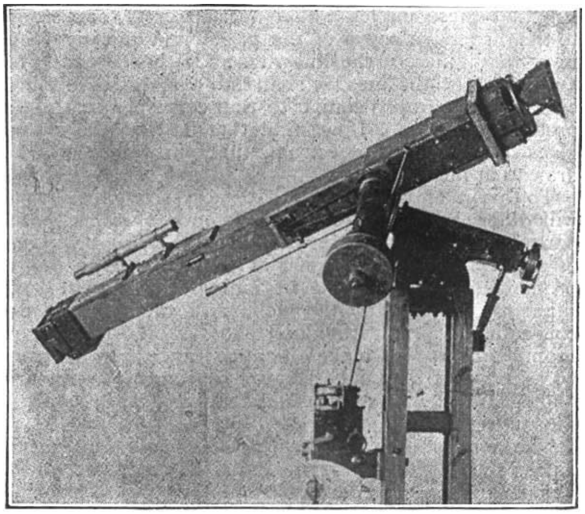

FIG. 7.—The 6-inch prismatic camera arranged for work during the Eclipse of 1893.

The upper edge of each dark slide was notched in three places corresponding to the positions of the three plates which it contained, and, as each plate came to the proper position for exposure, as the slide was pushed along, a spring catch automatically dropped into its place.

Upon the back of each dark slide six numbers were painted in clear white figures. A small series of numbers corresponded to the numbering of the thirty plates to be exposed during the eclipse, and a larger series indicated the exposures to be given to each plate, so that it was unnecessary to refer to any list.

These time-saving devices are of the highest importance in eclipse work, and too much attention cannot be given to them. The arrangements in West Africa worked admirably, and it was possible to change from one plate to another in about a second when a slide was once inserted, and to change the whole slide in five seconds. Longer intervals, however, were allowed to elapse between the exposures, in order that the instrument might steady itself, and to correct the backlash of the driving screw.

The instrument was focussed by photographing the spectra of some of the brighter stars. This is the only satisfactory method of focussing the prismatic camera, as rays from a star fall on the prism under exactly the same conditions as those from the eclipsed sun. If a slit and collimator be employed, identical conditions can only be obtained when the collimator is perfectly achromatic and absolutely adjusted for parallel rays.

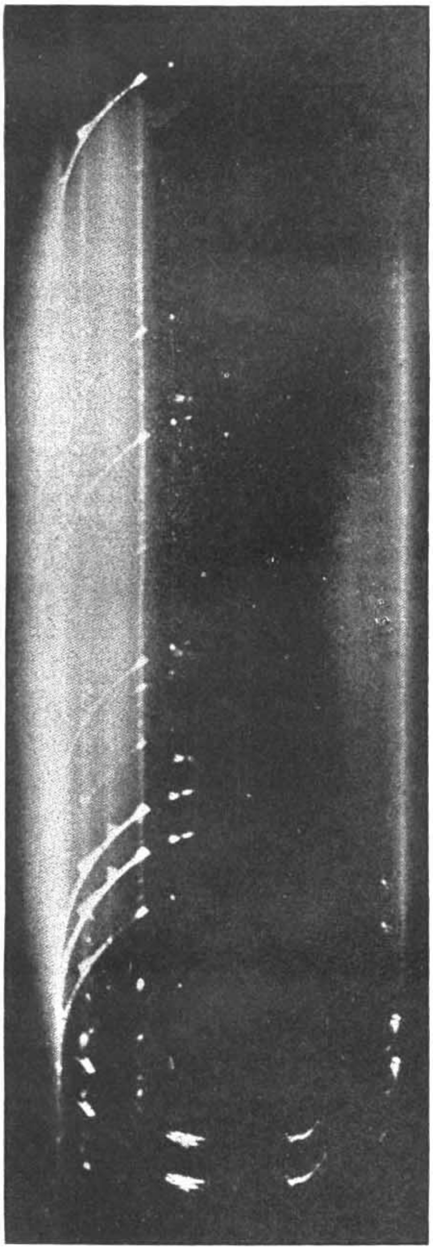

FIG. 8.—Untouched reproduction of photograph (African station) taken very shortly after the commencement of totality, the exposure being "instantaneous." At this phase of the eclipse a considerable arc of the chromosphere was visible, and its spectrum is therefore shown in addition to the spectrum of the higher reaches of some of the large prominences extending beyond the moon's limb. It will be seen that at H and K there are long arcs of chromosphere and prominences, the absent portions being of course obscured by the moon. One very small prominence is especially rich in lines.

I next come to the kind of result obtained by means of the unprecedented optical power employed in 1893, and for this purpose I reproduce two of the beautiful photographs obtained by Mr. Fowler.

It will be seen that we get more or less complete rings when we are dealing with an extended arc of the chromosphere, or lines of dots when any small part of it is being subjected to a disturbance which increases the temperature, and possibly the number of the different vapours present.

The interpretation of these photographs brings us in presence of many interesting and, at the same time, complicated problems. I cannot, however, refer to them here. I have set them out at length in the *Phil. Trans.* (vol. for 1896 A, p. 551).

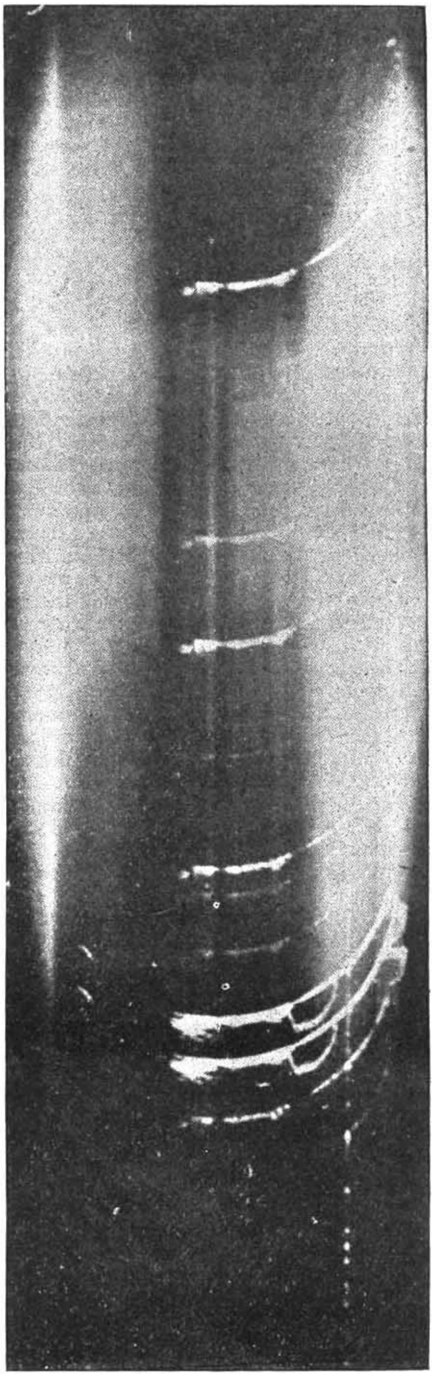

FIG. 9.—Photograph 21 (African station), taken shortly before the end of totality. A portion of the chromosphere on the other edge of the dark moon is now visible in addition to numerous prominences. It will be seen that one of the smallest prominences is rich in lines, and closely resembles that which appears in Fig. 8.

The instrument so successfully employed by Mr. Fowler was not the only one used in 1893. I had been able to equip Mr. Shackleton, one of the computers attached to the Solar Physics Observatory, with a large photographic spectroscope, deprived of its collimator, for use in Brazil. In this instrument we had two prisms of 60°. The object-glass was a Dallmeyer portrait lens 5D, aperture 3·25 inches, with a focal length of 19 inches. With this he was able to secure a second series of photographs.

The most important results recorded in 1893 may be stated as follows. We not only determined the wave-lengths with considerable accuracy of some 400 lines in the spectra of the chromosphere and prominences, and studied the distribution of the gases and vapour which gave rise to them, but the separation of the spectrum of the corona from that of the chromosphere was made perfectly clear. J. NORMAN LOCKYER.

(*To be continued.*)

WORK AND PROGRESS OF THE GEOLOGICAL SURVEY.[1]

THE first remark that will naturally occur to a geologist into whose hands this Report may come, will probably be one of satisfaction that the account of the work of the Geological Survey for the past year should have been brought out so early, and in a separate form in which the public can purchase it at a low price. But his pleasant surprise will soon be changed into feelings of another kind when he opens the volume and finds it printed, as heretofore, on poor, flimsy paper and in small, close type, so that the perusal of its pages becomes wearisome to the eyes. There could hardly be a stronger contrast to this style of production than that in which the Reports of the United States Geological Survey are issued. These, alike in paper, type and printing, are truly sumptuous publications placed alongside of the miserable efforts of our Stationery Office. Even Canada can afford to present the Reports of its Geological Survey in a form that should make our authorities blush. It is lamentable to see so much excellent scientific work offered to the world in such miserable guise. The Canadian Reports are not only better printed on better paper than ours, but they are actually sold at cheaper rates. Why cannot the mother-country afford to keep up to the level of her transatlantic colony?

The present Annual Report of the Director-General is the longest and most detailed which he has yet issued. It presents a clear picture of the activity of the Geological Survey over all the fields on which the staff is engaged, and enables the public to follow intelligently the progress of the work in the three kingdoms. The volume, or pamphlet of rather more than 100 pages, is divided into three sections, one dealing with the Geological Survey itself, one with the Palæontological Department, and one with the Museum of Practical Geology in Jermyn-street. The section that treats of the Survey consists of two portions, the first of which is devoted to the general statistics and administration of the three branches of the service in England, Scotland, and Ireland. It is interesting to notice in this, as in former Reports, the large extent to which the work of the Geological Survey is made use of for practical purposes. In different ways geology affords valuable information with regard to water-supply, reservoirs, drainage, soils, lines of railway, sites of houses, nature of building materials, and many other questions of daily life. The offices of the Geological Survey have become the recognised headquarters for information of this nature respecting the British Islands. The various Government Departments apply freely for assistance and advice, while the general public continues to make daily inquiries in regard to matters which involve a practical knowledge of geology.

The scientific results obtained by the Survey during the past year occupy the greater part of the Report, and are full of interest. The narrative of them is arranged in stratigraphical order, beginning with the oldest rocks. We are first taken into the district of Charnwood Forest, and shown the excellent work done there recently by Mr. W. W. Watts. We are then transported into the north-west of Scotland, and watch the labours of Messrs. Peach, Horne, and Clough among the mountains of Assynt and the hills of Skye. The wonderfully complex structure of the country between Cape Wrath and the southern promontory of Skye has now been worked out in detail, most of the maps of that region are published, and we may before long expect a full account of the whole belt of complication from the able band of surveyors who, amidst all the inclemencies of that boisterous climate, and all the physical difficulties of rugged mountain and shaking bog, have so skilfully unravelled the details of one of the most interesting and difficult geological districts in Europe.

In the northern, central and southern Highlands satisfactory progress continues to be made. In the far north Mr. Horne and Mr. Gunn have been at work among the "Moine schists" of Sutherland and Ross-shire. Mr. Barrow and Mr. Cunningham Craig are to be found among the glens and corries of the higher Grampians. Mr. Hinxman is busy among the rocks of Strathspey. On the west side of the country a chain of observers is stationed from the flanks of Ben Nevis to Loch Awe and the hills of Lorne. Mr. Grant Wilson is engaged among the schists and limestones of Loch Linnhe. Mr. Hill has continued his investigation of the metamorphic series around Loch Awe. Mr. Symes has made progress with the volcanic district of western Argyllshire; while Mr. Kynaston has been laying bare the secrets of Ben Cruachan. The work of each of these investigators is succinctly summarised by the Director-General, and attention is called to the more important results obtained in the examination of the younger or Dalradian schists of the Highlands. The mapping is likewise in progress among the metamorphic rocks of the Western Isles, Mr. Wilkinson having now completed the survey of Islay; while Mr. Gunn is prosecuting that of Arran.

One of the most important problems now engaging the attention of the Survey in the Scottish Highlands is connected with the position and relations of a belt of comparatively unaltered strata, wedged in between the schistose rocks and the Old Red Sandstone which has been faulted down against them. These strata, from their lithological characters, their sequence, and their including certain radiolarian cherts, are regarded as probably the equivalents of the closely similar rocks which lie in the Arenig division of the Silurian rocks of the Southern Uplands of Scotland. If such should eventually be proved to be their true age, they will have an important bearing on the age of at least the latest movements to which the Highland rocks owe their contorted and puckered structure. The problem, however, seems to become more difficult the longer it is studied. Last year Mr. Clough, who is engaged on its investigation, has found that no satisfactory line can be drawn between the presumably Lower Silurian strata and the general mass of the rocks of the southern Highlands. If any portion of these rocks should prove to be of Palæozoic age, it would be a notable discovery in British geology. In the meantime we must patiently await the result of the continuation of further research along the Highland border.

The mapping of the Cambrian rocks of the north-west of Scotland has now been completed by the surveys in Skye made last year by Mr. Clough. One of the most singular features of these ancient deposits is the persistence of the same lithological bands for a distance of

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[1] Annual Report of the Director-General of the Geological Survey of the United Kingdom for 1896. London: Printed for her Majesty's Stationery Office, 1897. Price 6*d*.